SURFICIAL DEPOSITS

Alluvial and colluvial

UPPER SANTA FI

GROUP SEDIMENTS

Pliocene

SURFICIAL DEPOSITS

Artificial-fill deposits

Alluvial deposits

Alluvium in stream channels and low-terrace deposits (Holocene)—Poorly sorted

Alluvium lies in channels of intermittent streams and beneath discontinuous

terraces less than about 3 m above modern stream channels, chiefly in the

deposits (Osw) and is susceptible to stream flooding. Deposits composed of

northern part of the map area. Unit Qa locally includes minor sheetwash

**Terrace alluvium (Holocene and late Pleistocene)**—Poorly sorted pebbly sand to

of modern intermittent streams in the northern part of the map area. Thin,

Sheetwash deposits (Holocene and late? Pleistocene)—Slightly pebbly to pebbly

and young alluvial-slope deposits (Qay). Unit Qsw locally includes small

unmapped deposits of stream alluvium (Qa). Low-lying areas of Qsw are

Old alluvium and calcic soils of the Llano de Albuquerque (early Pleistocene?

clast-supported sandy pebble gravel and locally thin lenses of cobbly pebble

gravel, beneath discontinuous terrace remnants 3–5 m higher than the channels

unmapped deposits of sheetwash and eolian sand (Qsw and Qea) locally mantle

unit Qt. The base of unit Qt is not exposed. Estimated thickness is 1–10 m

sand, silty sand, and locally scattered cobbles that mantles old alluvial-slope

deposits (Qao). Small, unmapped deposits locally overlie terrace alluvium (Qt)

susceptible to sheet-and-stream flooding and to gullying. Disturbed areas of Qsw

probably are susceptible to wind erosion and deposition. Estimated thickness is

and Pliocene)—Slightly pebbly sand reworked mainly from the gravel unit of

the upper Santa Fe Group sediments (Tg) and probably was deposited chiefly as

sheetwash and alluvium of intermittent streams along the western escarpment of

the Llano de Albuquerque near the southwest corner of the map area. The upper

horizons with stage II to IV carbonate morphology. These soils are well exposed

escarpment of the Llano de Albuquerque. Slightly (< 20 percent) pebbly, very

present may be eolian in origin. Deposits of slightly pebbly sand in the lower part

of the unit locally contain one or more minor disconformities. The lower part of

QTa locally fills shallow channels, inset into the underlying unit (Tg), that have

85–140 cm thick. The K horizons have strong stage III and stage IV morphology

structure, whereas the rest of the K horizon commonly is massive and grades

and the underlying Bk horizon are formed in slightly pebbly sand. These

characterized by carbonate-rich nodules, some as large as 12 cm in diameter

Unit QTa is mantled by deposits of eolian sand (Qea) and sheetwash (Qes).

deposits, undivided (Holocene and late Pleistocene)—Alluvium in channels of

termittent streams, beneath low terraces (Qa), and young alluvial-slope

Young alluvial-slope deposits (Holocene and late Pleistocene)— Gently sloping

deposits (Oay) are mapped as an undivided unit in the northeastern part of the

eposits composed chiefly of pebbly sand, pebble gravel, and locally, thin lenses

of cobbly pebble gravel. These sediments are derived in part from upper Santa Fe

Group sediments (Tg. Tps. and Ts). Unit Qay consists chiefly of stream alluvium

and minor fan deposits that locally are overlain by thin unmapped sheetwash

locally mantles valley sides and hill slopes. It is topographically lower and

deposits (Qsw). Unit Qay commonly underlies gently sloping surfaces, and it

younger than unit Qao, and locally grades into and locally includes unmapped

stream alluvium (Oa). Low-lying deposits adjacent to modern stream channels

flooding. Deposits of slightly pebbly, very fine to medium sand are subject to

are susceptible to flooding. Gently sloping deposits are susceptible to sheet

Alluvium and colluvium, undivided (Holocene and late Pleistocene)—Undifferentiated

sheetwash deposits, stream-channel deposits, and minor fan deposits that

commonly overlie upper Santa Fe Group sediments (Tg and Ts). Unit Qac

and matrix-supported, slightly cobbly, pebble gravel that has a sand matrix.

debris-flow deposition and gullying. Estimated thickness is 1–5 m

Old alluvial-slope deposits (late and middle? Pleistocene)—Gently sloping

commonly ranges from pebbly, very fine to medium sand to poorly sorted, clast-

Low-lying deposits of unit Qac are susceptible to stream flooding and locally to

deposits composed chiefly of pebbly sand, pebble gravel, and locally, thin lenses

derived in part from upper Santa Fe Group sediments (Tq). Unit Qao consists

sheetwash deposits (Qsw). Commonly mapped in fractional unit Qsw/Qao,

except for deposits at the northeast corner of the map area. Unit Qao commonly

forms a broad alluvial surface, and is topographically higher and older than unit

Qay. Low-lying deposits adjacent to modern stream channels are susceptible to

flooding. Gently sloping deposits are susceptible to sheet flooding. Deposits of

slightly pebbly very fine to medium sand are subject to gullying. Estimated

Active eolian sand (Holocene)—Quartz-rich, very slightly calcareous, very fine to

medium sand that lacks soils and supports little to no vegetation. The sand-size

fraction is mostly very fine to fine with a minor amount of medium sand. The

blowing sand. Cross stratification is locally exposed in blowouts. Unit Qea is

locally present along the western escarpment of the Llano de Albuquerque, near

the western boundary of the quadrangle. The unit locally includes small deposits

of inactive eolian sand and sheetwash (Qes). Unit Qea is subject to erosion and

deposition by wind. Maximum thickness is about 10–15 m near the northwest

**Pleistocene**)—Quartz-rich, non-calcareous to calcareous, locally slightly pebbl

shrubs, and annual plants. Unit Qes mantles old alluvium and calcic soils of the

Llano de Albuquerque (QTa), and is the most extensive surficial unit in the map

and cobbly, very fine to medium sand that supports a sparse cover of grasses.

area. Thin unmapped deposits of active eolian sand (Qea) locally overlie Qes

near the western boundary of the map area. Scattered pebbles, cobbles, and

K-horizon fragments in Qes probably were derived from the underlying calcic

soils and sediments (QTa and Tg) and probably were moved upward by burrow-

ing animals. Some or much of the sand probably was deflated from upper Santa

Fe Group sediments that are exposed along the western escarpment of the Lland

de Albuquerque, and was deposited by southwesterly or westerly winds. Some

distant sources, such as the flood plain of the Rio Puerco, about 5–8 km west of

the map area. Unit Qes forms sand sheets and locally widely spaced sand dunes

that are about 1–5 m high. Some of these dunes resemble linear dunes, but they

probably are modified parabolic dunes (Madole, 1995; Wells and others, 1990).

The other dunes are simple and compound parabolic dunes. Arms of the simple

open to the west-southwest. The shape and orientation of these dunes indicate

that they were formed by paleowinds from the west-southwest. Most of the dunes

are in a 4-km wide, east-northeast-trending belt. The southern limit of this belt is

just north of the large deposits of fill material (af) at the Soil Amendment Facility

(sec. 22, T. 11 N., R. 1 E.). Surface soils commonly have color (cambic, Bw)

locally overlie Bk horizons about 10–45 cm thick that have stage I-II carbonate

morphology. Buried soils in Qes are exposed along the western escarpment of

and weak argillic (Bt) horizons about 15–30 cm thick. The Bw or Bt horizons

the Llano de Albuquerque. They have cambic and weak argillic B horizons,

and modified parabolic dunes commonly are oriented about N. 70–80° E. and

of the silt- and clay-size fraction in Qes may have been derived from more

surface of unit Qea commonly is characterized by small ripples produced by

Eolian deposits

Eolian and alluvial deposits

Qes Inactive eolian sand and sheetwash deposits, undivided (Holocene and late

corner of the map area

chiefly of stream alluvium and minor fan deposits that are commonly mantled by

of cobbly pebble gravel near the northeastern corner of the map area. Unit Qao is

horizons locally are as thick as 200 cm, and have stage II-III morphology

Exposed thickness is commonly 1.5–3 m; estimated thickness is 6 m

Alluvium in stream channels, low-terrace deposits, and young alluvial-slope

Alluvial and colluvial deposits

map area. Estimated thickness is 1–15 m

gullying. Estimated thickness is 1–15 m

downward to coalesced, carbonate-rich nodules. The latter part of the K horizon

in the uppermost 5–40 cm. The uppermost part of the K horizon locally has platy

as much as 1.5 m of relief. The calcic soils at the top of the unit apparently are

formed in slightly pebbly sand. Those soils have K horizons that are about

fine to very coarse sand beneath soil K horizons appears to be alluvial in origin

however, some of the slightly pebbly, very fine to medium sand that is locally

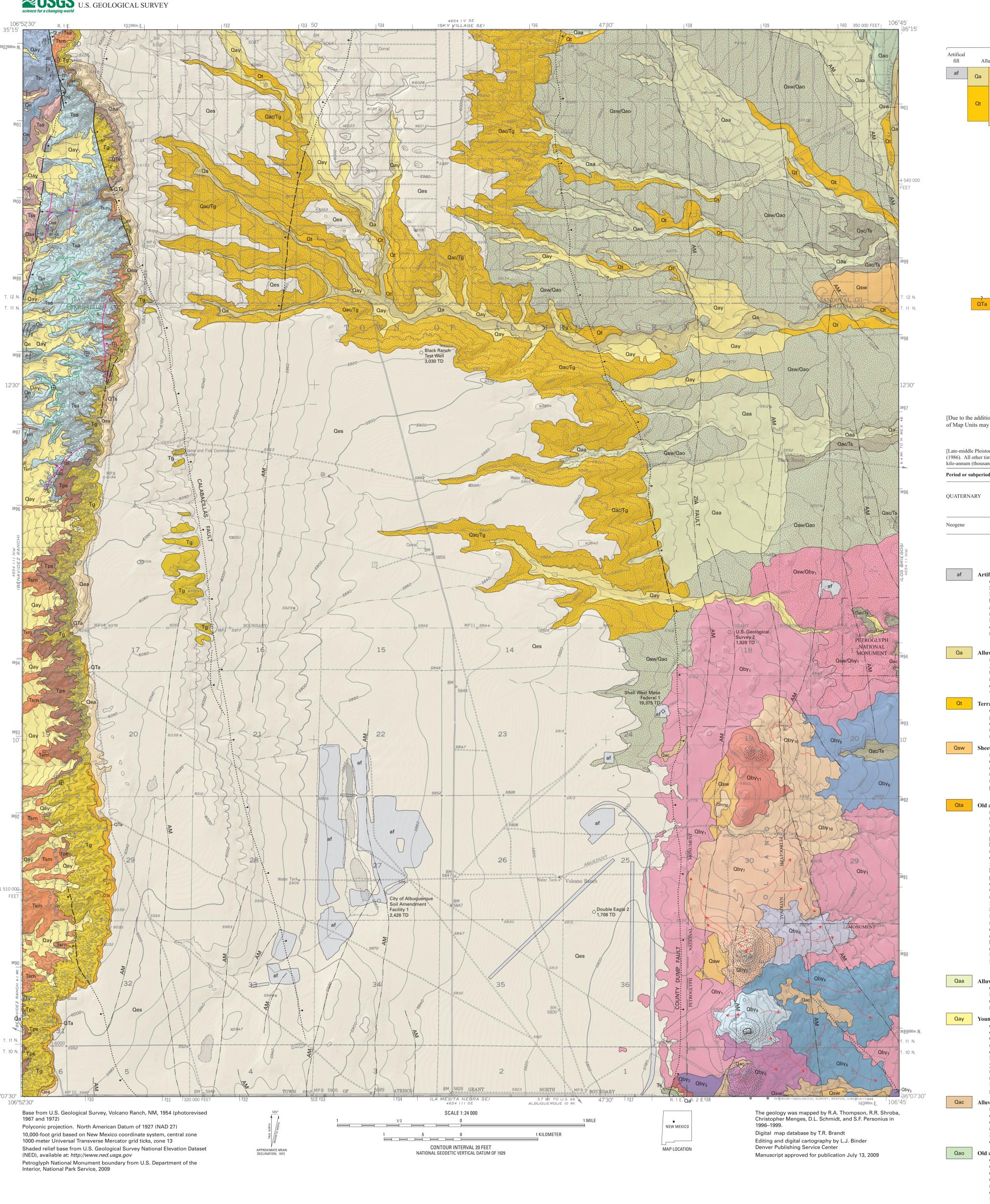
part of the unit contains calcium carbonate enriched soils that have Bk and K

along the western escarpment and, locally, in outcrops along the eastern

sand to sandy pebble gravel; locally contains thin lenses of cobbly pebble gravel.

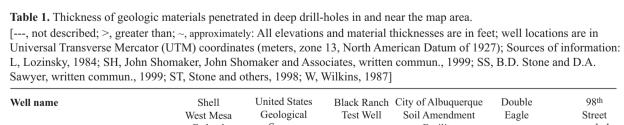
well-sorted silty sand are susceptible to gullying. Estimated thickness is 1–10 m

CORRELATION OF MAP UNITS

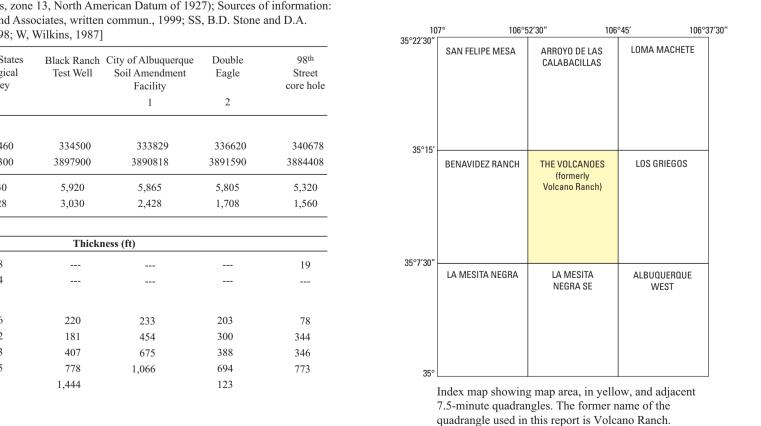


The Volcanoes quadrangle (this report)		Albuquerque–Rio Rancho metropolitan area and vicinity (Connell, 2006)	Albuquerque 30' × 60' quadrangle (Williams and Cole, 2007)	Part of the Ceja del Rio Puerco area north of the Sandoval County line (Tedford and Barghoorn, 1999)		
Gravel unit of the upper Santa Fe Group sediments (unit Tg)	Upper Santa Fe Group sediments undivided (unit Ts)	Upper sand and gravel member Ceja Formation	Ceja Formation	Ceja Member		
Pebbly sand unit of the upper Santa Fe Group sediments (unit Tps)	f	Upper sandy subunit Atrisco member	?	Arroyo Ojito Formation		
Tan sand and mud unit of the upper Santa Fe Group sediments (unit Tsm)		Ceja Formation	Loma Barbon Member "Middle red" formation	Loma Barbon Member Arroyo Ojito Formation		
Tan sand unit of the upper Santa Fe Group sediments		Atrisco member Ceja Formation Navajo Draw Member				
(unit Tsa)		Arroyo Ojito Formation				
Tan sand and clay unit of the upper Santa Fe Group sediments (unit Tsc)  Silty sand unit of the upper Santa Fe Group sediments (unit Tss)		upper part of Cerro Conejo Formation	Cerro Conejo Member "Middle red" formation	Cerro Conejo Member Arroyo Ojito Formation		

Figure 2. Generalized stratigraphic relations of Santa Fe Group sediments recently mapped in The Volcanoes quadrangle. The Navajo Draw Member of the Arroyo Qiito Formation is overlain by and is older than, the Loma Barbon Member of the Arroyo Qiito Formation (Connell, 2006). About 18 km north of The Volcanoes quadrangle, volcanic ash in the middle of the Loma Barbon Member yielded an <sup>40</sup>Ar/<sup>39</sup>Ar age (sanidine) of 6.81 ± 0.14 Ma (Connell and others, 1999), indicating that the underlying Navajo Draw Member is older than 6.8 Ma. The tan sand and clay unit (Tsc) and the silty sand unit (Tss) of the upper Santa Fe Group sediments on The Volcanoes quadrangle are equivalent to the upper part of the Cerro Conejo Member of the Arroyo Ojito Formation, mapped and described by Tedford and Barghoorn (1999). The lower half of the Cerro Conejo Member contains an air-fall ash that yielded a K/Ar age (biotite) of 13.64 ± 0.09 Ma; the middle part contains vertebrate fossils of late Barstovian age (North American land mammal age; 12–14 Ma; Tedford and Barghoorn, 1999). This correlation and age control for the Cerro Conejo Member suggest that the tan sand and clay unit (Tsc) and the silty sand (Tss) on The Volcanoes quadrangle are less than 12 Ma.



Well name	Shell West Mesa Federal	United States Geological Survey	Black Ranch Test Well	City of Albuquerque Soil Amendment Facility	Double Eagle	98 <sup>t</sup> Stre core h		
Well number	1	2		1	2			
Well location								
<b>UTM Easting</b>	337600	338460	334500	333829	336620	3406		
<b>UTM Northing</b>	3893180	3894300	3897900	3890818	3891590	38844		
Ground surface elevation (ft)	5,775	5,730	5,920	5,865	5,805	5,32		
Total Depth (TD, ft)	19,375	1,828	3,030	2,428	1,708	1,56		
-	Thickness (ft)							
Surficial deposits		8				19		
Basalt		34						
Santa Fe Group								
Gravelly sediment	~200	196	220	233	203	78		
Medium to coarse sand	~180	592	181	454	300	344		
Silty sediment	~400	443	407	675	388	346		
Medium sand	~1,600	555	778	1,066	694	773		
Fine to medium sand	6,170		1,444		123			
Unit of Isleta no. 2	7,170							
Galisteo Formation	~1,110							
Cretaceous rocks, undivided	~1,655							
Jurassic rocks, undivided	~900							
Total thickness of Santa Fe Group	8,550	>1,786	>3,030	>2,428	>1,708	>1,541		
Sources of information	L, SS	W, SS	SS, SH	SS	SS	ST		



**DESCRIPTION OF MAP UNITS** about 40-70 cm thick, above Bk horizons that have stage I-II carbonate morphology. These buried soils overlie old alluvium and calcic soils of the Llano de [Due to the addition of a shaded relief base, colors in the Description of Map Units and Correlation Albuquerque (QTa) and they are overlain by active eolian sand (Qea). Unit Qes of Map Units may not exactly match unit colors on the map] locally includes small, unmapped deposits of stream alluvium (Qa) and active eolian sand (Qea). Low-lying deposits of Qes are susceptible to stream and sheet flooding and gullying. Disturbed deposits of unit Qes are susceptible to erosion Divisions of Quaternary and Neogene time and deposition by the wind. Wells and others (1990) identified three major [Late-middle Pleistocene and middle-early Pleistocene time boundaries are from Richmond and Fullerton episodes of sand deposition, at about 15–9 ka, 6–2 ka, and after 1.5 ka, in the (1986). All other time boundaries are from U.S. Geological Survey (2007). Ages are expressed in ka for Chaco dune field about 130 km northwest of the map area. Comparison of the kilo-annum (thousand years) and Ma for mega-annum (million years) degree of soil development suggests that sand bodies in unit Qes may have been deposited during one or more of those eolian episodes. Unit Qes probably is thickest in the 4-km wide, east-northeast trending belt north of the Soil Amendment Facility. Exposed thickness is 1–3 m; estimated thickness is 1–10 m 0–11.5 ka

LAVA FLOWS AND RELATED DEPOSITS

OF ALBUQUERQUE VOLCANOES

Relative age uncertain Oby<sub>4</sub> Oby<sub>5</sub> Oby<sub>6</sub> Oby<sub>7</sub> Oby<sub>8</sub> Oby<sub>9</sub>

Active and inactive eolian sand and sheetwash deposits, undivided (Holocene and 11.5-132 ka late Pleistocene?)—Active eolian sand (Qea) and inactive eolian sand and 132–788 ka sheetwash deposits (Qes), mapped as an undivided unit in one area near the 788 ka-1.81 Ma northwest corner of the map area. Estimated thickness is 1–10 m 1.81-5.33 Ma Old sheetwash deposits, eolian sand, and calcic soils associated with fault scarps 5.33-23.0 Ma (early? Pleistocene and Pliocene?)—Mostly sandy sheetwash deposits, eolian sand, intercalated calcic soils, and possibly minor stream alluvium form wedge-shaped deposits on downthrown fault block of gravel unit of the upper Santa Fe Group sediments (Tg) on the east side of the Calabacillas fault and an unnamed fault along the western escarpment of the Llano de Albuquerque, near the northwestern corner of the map area. Multiple buried calcic soils with stage II-III carbonate morphology indicate recurrent episodes of deposition, surface Artificial fill deposits (latest Holocene)—Compacted and uncompacted fill material stability, and soil development after fault displacement (Wright, 1946: Machette composed mainly of silt, sand, and rock fragments. At the City of Albuquerque and others, 1997). The amount of secondary calcium carbonate in the surface Soil Amendment Facility unit af consists in part of decomposed sewage sludge and the disconformity-bound buried soils preserved in the upper 33.8 m of the Mapped chiefly beneath buildings and runways at Double Eagle II Airport, unit QTs (Machette and others, 1997, site no. 5) divided by the average rate of beneath Paseo del Volcan, in fields at the Soil Amendment Facility, and in spoi secondary calcium carbonate accumulation in the Albuquerque area (Machette, and storage piles at small quarries in basalt (Qby<sub>1</sub>) in the southeastern part of the 1985, table 3) suggests that these soils represent at least 1.3 m.y. of soil formamap area. At the Soil Amendment Facility and probably elsewhere, unit af tion. A similar assemblage of fault-related deposits and buried soils is exposed at locally includes small areas of disturbed ground where the land was modified b El Rincon, about 1 km south of the map area (Shroba and others, 2003). Exposed earth-moving equipment so that the original geologic material could not be thickness is as much as 45 m (Wright, 1946) recognized, but little or no fill was emplaced. Estimated thickness is 1–5 m LAVA FLOWS AND RELATED DEPOSITS OF ALBUQUERQUE VOLCANOES

QUATERNARY

by black rectangle.

de Albuquerque in the southeast part of the quadrangle and parts of the adjacent La Mesita Negra SE (Shroba and others, 2003) and Los Griegos (B.D. Stone and others, U.S. Geological Survey unpublished mapping) 1:24,000-scale quadrangles, respectively. Kelley and Kudo (1978) identified five prominent cinder cones and a number of vent-related features. However, satellite vents ormed along the entire length of the inferred fissure. Lava flows erupted from vents along fissures and flowed predominantly eastward for distances as great as 5 km, toward the Rio Grande. These flows formed a prominent basalt plateau that covers 60 km<sup>2</sup> of the Llano de Albuquerque geomorphic surface. Basalt flows are exposed prominently along the escarpment on the eastern eroded margin of the Llano de Albuquerque, where their base is about 70–100 m above the modern Rio Grande flood plain. Volcanic map units are delineated on the basis of lithology, morphology, and stratigraphic position. Units composed primarily of lava flows typically represent individual eruptive events; they are characterized by one or more flows that consist of multiple flow lobes. Locally, the volcanic map units include interbedded pyroclastic deposits. Temporally equivalent near-vent pyroclastic deposits associated with lava flow eruptions are denoted by a stipple pattern overlay. Detailed descriptions of facies textures of pyroclastic deposits and lava flows are given in Kelley and Kudo (1978), Smith and others (1999), and Crumpler (1999) A middle Pleistocene age assignment for the volcanic rocks is based on three independent dating techniques. Analytical uncertainty for analyses reported by each technique exceed the total range of reported ages and none of the ages reflect relative stratigraphic position based on mapping within this quadrangle and adjacent 1:24,000-scale quadrangles to the east and south. The preserved morphology of lava flows and the absence of significant erosional unconformities between eruptive units suggest all mapped volcanic units were emplaced within a relatively short time interval. Geissman and others (1990) also reported directions of remanent magnetization of near-vent deposits and proximal lava flows that are statistically indistinguishable from those determined for distal flows at the base of the volcanic section. The consistent but atypical directions reported suggest a short duration of magmatic activity during one of the Brunhes Chron polarity excursions A whole-rock K/Ar determination of 0.19±0.04 Ma was reported by Bachman and Mehnert (1978) from Albuquerque Volcanoes, however, an erroneous reported sample location precludes dentification of the original sample location or map unit dated. Geissman and others (1990) eported a weighted mean K/Ar age of 0.155±0.047 Ma, based on determinations for three samples with reported ages ranging from <0 to 0.17±0.05 Ma but report no sample locations. Singer and others (2008) report an average <sup>40</sup>Ar/<sup>39</sup>Ar isochron age of 218±14 ka based on multiple samples from each of six lava flows and correlate associated paleomagnetic data with the Pringle Falls geomagnetic excursion. No sample locations are reported for this study. A <sup>238</sup>U/<sup>230</sup>Th isochron letermination for three whole rock samples from units Qby<sub>2</sub>, Qby<sub>9</sub> and Qby<sub>11</sub> yielded an age of  $0.156\pm0.029$  Ma (Peate and others, 1996). ava flows and cinder deposits were mapped in both The Volcanoes quadrangle and the adjacent a Mesita Negra SE quadrangle. At the southern edge of the volcanic field intercalated gravel of inferred middle Pleistocene age, which lacks obvious soils, separates older cliff-forming basalt flows from younger flows (Shroba and others, 2003). Unit Qbo (old lava flows of Shroba and others, 2003) is exposed in the La Mesita Negra SE quadrangle, however only younger flows  $(Oby_{1-1})$  above the middle Pleistocene gravels are exposed on the The Volcanoes quadrangle. To maintain the same terminology for the volcanic units in both quadrangles, all of the volcanic units

[The Albuquerque Volcanoes is a 10-km-long chain of basalt cones and associated lava flows that

erupted from fissure vents, resulting from magma intrusion along conduits following the prominent

north-south trending faults in the Albuquerque Basin (fig. 1). The volcanic field overlies the Llano

numbering scheme used to designate deposits of any given eruptive event does not necessarily Lava flows and related deposits (middle Pleistocene)—Medium- to dark-gray tholeiitic lava flows (48–50 wt percent SiO<sub>2</sub>, 4 wt percent Na<sub>2</sub>O+K<sub>2</sub>O, 1.5 wt percent TiO<sub>2</sub>) and near-vent pyroclastic deposits associated with Hawaiian-type fissure eruptions. Deposits proximal to vents include cinder deposits, spatter deposits, spatter agglutinate, breccia and clastogenic lava flows, and locally, thin pahoehoe lava flows that typically are radially distributed around small cones and cone remnants. The lava flows vary in thickness from < 1 m to several meters. Both near-vent deposits and lava flows contain ubiquitous phenocrysts (< 1–2 mm) of olivine and plagioclase in a fine-grained intergranular matrix of plagioclase, Fe-Ti oxides, augite, and interstitial glass

in The Volcanoes quadrangle are designated as young (for example, Qby<sub>1</sub>, young lava flow unit 1).

Where mapped eruptive units (Qby<sub>1</sub>–Qby<sub>11</sub>) are non-contiguous or stratigraphic position is

obscured by poor exposure, even relative age between some units is uncertain. Consequently the

Lava flow unit 11—Near-vent pyroclastic deposits and intercalated lava flows of Bond volcano. Lava flows are predominantly shelly pahoehoe with locally developed as flow texture. Lava tubes are common as are push-up structures and rafted pyroclastic deposits. Near-vent deposits are heterogeneous and include cinder, spatter, agglutinate, and clastogenic lava flows. Thickness is 40 m **Lava flow unit 10**—Medium- to dark-gray discontinuous shelly pahoehoe to aa

lava flows (<1 m to 2 m thick) erupted from vents at or near the current location of Bond volcano. Forms broad plateau east of Bond and Butte volcanoes. Lava tubes and ramp structures are common. Thickness is 1–2 m Lava flow unit 9—Discontinuous, rubbly, dark-gray, thin (1–2m), vesicular lava flows in the southeast corner of the map area. Lava flows are early eruptive

products from vents near Bond and Butte volcanoes. Thickness is 2–3 m Lava flow unit 8—Medium- to dark-gray proximal lava flows and near-vent pyroclastic deposits of Black volcano. Lower flows are dark-gray, hummocky and scoriaceous. Two overlying cones consist of cinders, scoria, spatter, agglutinate and intercalated lava flows (Kelly and Kudo, 1978). The northernmost flanks of Black volcano consist predominantly of cinders and have been

removed by mining. Thickness is 2–3 m

Lava flow unit 7—Proximal lava flows and associated near-vent pyroclastic deposits of Vulcan volcano. Medium- to dark-gray lava flows comprise a broad highland north of prominent central cone. Lava flows are predominantly shelly pahoehoe with locally developed aa flow textures. Lava tubes are common as are push-up structures and rafted pyroclastic deposits. Near-vent deposits are heterogeneous and locally include cinder, spatter, agglutinate, clastogenic lava flows and minor columnar jointed flows exposed in breeched lava ponds (Smith and others, 1999). Locally these deposits are cut by dikes. Near-vent deposits on guarried north side of Vulcan volcano contain abundant partially melted. vesiculated xenoliths of sandstone. Thickness is 50 m

products from vents of Volcan volcano. Thickness is 1–3 m Lava flow unit 5—Medium- to dark-gray vesicular lava flows exposed along the northern and eastern flanks of cone J (Kelley and Kudo, 1978) and southern flanks of vent areas of Black volcano (Kelley and Kudo, 1978). Lava flows typically are thin (1–2 m), and locally are interbedded with near-vent deposit (scoria, cinders, and spatter associated with fire fountain eruptions from J A volcano and Black volcano). Locally, ramp structures, push-up features, and

**Lava flow unit 6**—Discontinuous, rubbly, dark-gray, thin (1–2m), vesicular lava

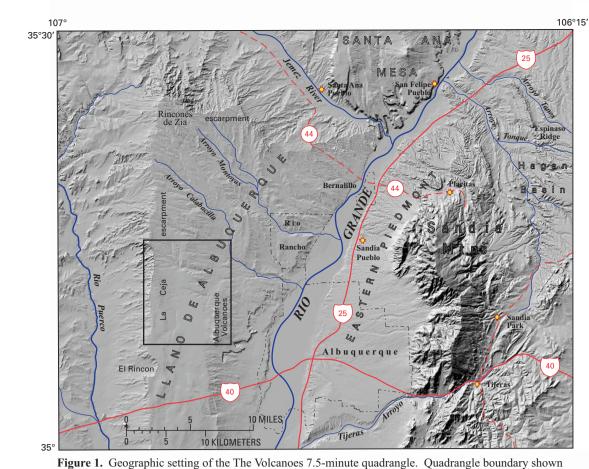
flows near the southeast corner of the map area. Lava flows are early eruptive

small lava tubes are common. Exposed thickness is 4–5 m in map area; base not

Lava flow unit 4—Discontinuous, rubbly, dark-gray, thin (1–2m), vesicular lava lows near the southeast corner of the map area. Lava flows are early eruptive products from vents of Black volcano. Thickness is 2–3 m Lava flow unit 3—Discontinuous, rubbly, thin (1-3 m) dark-gray vesicular lava flows 1.5 km southwest of Black volcano. Elsewhere, the unit forms an indistinct low-relief apron around fissure vents and above cliff-forming flows of

unit Obo south of the map area (Shroba and others, 2003). Push-up structures and rafted pyroclastic deposits are common. Exposed thickness in map area is 2 m; base not exposed Lava flow unit 2—Medium- to dark-gray lava flows exposed along an unnamed wash on the southwest margin of the volcanic field, east of the County Dump fault, on the southern boundary of the map area. Also present as discontinuous and partially covered flows southeast of their presumed vents in the adjacent La

Mesita Negra SE quadrangle (Shroba and others, 2003). Typically thin (1–2 m) lava flows exhibit transitional pahoehoe to aa surface forms. Thickness is 2–6 m **Lava flow unit 1**—Medium- to dark-gray lava flows overlying gravel near southern limit of basalt south of the quadrangle (Shroba and others, 2003). Typically thin (1–2 m) lava flows characterized by surface forms transitional from pahoehoe to aa, parallel to low-relief flow lobes along flow direction. Largest volume eruptive unit in the map area, likely erupted from vent areas obscured by younger eruptions (Qby<sub>2</sub>–Qby<sub>11</sub>). Wilkins (1987) reports a thickness of 34 ft (10 m) in U.S. Geological Survey well 2. Thickness is 3–10 m



UPPER SANTA FE GROUP SEDIMENTS [Upper Santa Fe Group sediments are well exposed and mapped along the western escarpment of the Llano de Albuquerque in the western part of the map area. Most of them are fluvial in origin. Some of them are finer grained than temporally correlative sediments near the Sand Hill fault just north of the of the map area (Tedford and Barghoorn, 1999) and near the northern margin of the Llano de Albuquerque, about 18 km north of the map area (Connell and others, 1999). Wright (1946) described the upper Santa Fe Group sediments along the western escarpment, and prepared a fence diagram showing major lithologic variations along more than 40 km of nearly continuous outcrop. Lambert (1968) and Kelley (1977) measured stratigraphic sections consisting chiefly of interbedded gray gravel and sand at the top of upper Santa Fe Group sediments at El Rincon, about 4 km south of the southwest corner of The Volcanoes quadrangle. In both of these sections, the base of the carbonate-enriched soil on the Llano de Albuquerque was defined as the eroded top of the Santa Fe Group sediments. Kelley's 64.4-m-thick measured section defines a

> his Santa Fe Formation. Lambert's 94.9-m-thick measured section also included sediments composed of sands, silts, and clays, below the lowest gray sand-and-gravel bed. Lambert did not define a base for his "Upper buff formation"; nevertheless he recognized, as did Kelley (1977), the same stratigraphic horizon marking the much coarser sand and gravel above silt and fine sand.] Gravel unit of the upper Santa Fe Group sediments (Pliocene)—Gray, sandy, pebble-and-cobble gravel interbedded with gray, pebbly, medium to coarse sand and sparse coarse gravel that locally contains abundant cobbles and rare boulders as long as 1–1.5 m. Gravel is mostly clast supported. Gravel and sand interbeds are moderately well sorted. Most of the deposits are poorly indurated; locally they contain carbonate cement, which is most abundant beneath the carbonate-

> base at the bottom of the lowest, gray sand-and-gravel bed; he named this unit the Ceja Member of

enriched soil in the overlying unit (QTa). Pebbles and cobbles are composed of sandstone, porphyritic volcanic rock, red granite, gneiss, foliated granite, chert (including Pedernal chert of Maldonado and Kelley, 2009), and sparse quartzite, petrified wood, and basalt. A similar clast assemblage was reported for unit Tg, about 6 km south of the map area (Cole and others, 2007, table S-1). Large boulders are rare and are mostly Pedernal chert, sandstone, and basaltic flow rock. A clast count by Lambert (1968, p. 83) at his El Rincon section indicates 34 percent Precambrian igneous and metamorphic clasts, 46 percent Mesozoic sedimentary clasts, and 20 percent Tertiary volcanic clasts. Pebbles typically are subangular; cobbles are subangular and subrounded. The lower part of unit To is more poorly sorted than the upper part. The lower part includes light-gray sand and small-pebble gravel that at outcrop scale has small fluvial channels less than sorted. It contains medium-gray, commonly coarse gravel and sand that at outcrop scale fills large fluvial channels tens of meters deep and hundreds of meters wide. The upper part of unit Tg locally fills channels cut into underlying units (Tps and Tsm). Sediment-transport direction near the northwest corner of the map area was toward the southeast (Connell, 2006, plate 1) and toward the northeast to southeast at El Rincon (B.D. Stone, U.S. Geological Survey, written commun., 1998). The provenance of some of the Cretaceous sandstone clasts may be far to the northwest in the Colorado Plateau. Some of the Precambrian clasts were probably eroded from the Nacimiento Mountains, about 40 km north of the map area. Clasts of Pedernal chert probably were derived from the Abiquiu Formation (Maldonado and Kelley, 2009) farther north. The upward coarsening and the presence of large channels in the upper part of unit Tg may be related to cooler and wetter climatic conditions and greater stream power (Cole and others, 2001, 2002; Cole and Stone, 2002). Tan sand, similar to that in the underlying pebbly sand unit (Tps), locally forms a conspicuous stratigraphic marker (key bed) in the lower part of unit Tg. The sand body is about 5 m thick for a distance of about 1.2 km. The eroded upper contact of unit Tg is well exposed and abrupt beneath unit QTa. Unit Tg is equivalent to the upper sand and gravel member of the Ceia Formation of Connell (2006) and the upper sand and gravel unit of the Ceja Formation (Maldonado and others, 2007; Williams and Cole, 2007; see fig. 1 this report). The Pliocene age assignment for unit Tg is based in part on Blancan North American land mammal ages (Pliocene) for vertebrate fossils in temporally and lithologically correlative sediments near Albuquerque (Tedford, 1981; Morgan and Lucas, 1999; Tedford and Barghoorn, 1999), which Morgan and Lucas (1999) conclude are most likely middle Blancar (2.5–3.7 Ma). This age is consistent with the presence of a 2.6-Ma tephra in the

is missing on the hanging-wall block of the Calabacillas fault Pebbly sand unit of the upper Santa Fe Group sediments (Pliocene) —- Tan, fine to medium sand (60–80 percent of unit) interbedded with gray, pebbly, medium to coarse sand and gray, sandy pebble gravel (20–40 percent of unit). Unit Tps locally contains thin beds of tan silt and reddish-brown clay, especially in the lower part of the unit. Gray sand-and-gravel layers commonly are 1–2 m thick and are weakly cemented by calcium carbonate. Interbeds of poorly sorted tan sand are more than 2 m thick and are poorly consolidated. Unit Tps grades upward into the overlying gravel unit (Tg). Erosion of unit Tps commonly produces step-like topography; the gray sand and gravel forms low risers and the tan sand forms long treads or flats. Much of unit Tps and the underlying unit Tsm are similar in appearance, due to the abundance of tan sand in both of these units. Map relationships near the southwest corner of the map area suggest a prominent erosional unconformity at the base of unit Tps. Locally as much as 30 m thick

upper part (Connell and others, 2001) and a 3.0-Ma basalt flow below the upper

sand and gravel unit of the Ceja Formation (Maldonado and others, 1999, 2007).

Map relationships near the southwest corner of the map area suggest a prominent

erosional unconformity at the base of unit Tg. Locally as much as 40 m thick, but

Tan sand and mud unit of the upper Santa Fe Group sediments (upper **Miocene**)—Tan, fine to medium sand (70–90 percent of unit) and interbeds of pale reddish-brown and yellowish- to dark-greenish-brown clay, silty clay, and clayey silt (10–30 percent of unit). Layers of tan sand are poorly consolidated and about 2–6 m thick. They commonly have subtle fluvial sedimentary structures, such as cross-bedding. Beds of clay and silt are moderately consolidated and are 0.5–3 m thick. These beds stand in subtle relief compared to beds of more easily eroded tan sand. Granules and pebbles are sparse to absent. Sediment-transport direction probably was toward the south (Williams and Cole, 2007). The clay beds are interpreted to be the tops of upward-fining, depositional sequences. The upper contact of unit Tsm commonly was placed at the top of the highest clay beds. Map relationships suggest that the lower part of unit Tsm grades northward into unit Tsa. The lower contact of unit Tsm is not exposed in the map area. Exposed thickness varies from less than 1 to as much as 40 m

Tan sand unit of the upper Santa Fe Group sediments (upper Miocene)— Mostly

tan, poorly sorted, subangular, fine to medium sand that consists of medial and proximal (near-fault) facies east of the Sand Hill fault. The medial facies consists chiefly of upward-fining depositional sequences commonly about 5–7 r thick. These sequences commonly consist of a (1) lower granule to fine-pebble gravel, about 0.5–1.5 m thick; (2) a middle tan fine to medium sand, about 4 m thick; and (3) an upper (partly dissolved?) carbonate-enriched paleosol (formed in silty fine sand), about 0.5–1.5 m thick. Six paleosols are preserved in the upper 50 m of unit Tsa east of the Sand Hills fault. The paleosols consist of pale-gray to pale-brownish-gray, moderately consolidated, bioturbated, calcareous, silty sand that contains nodular carbonate and scattered small pebbles. Each of the six paleosols suggests episodic fault displacement (east side down) followed by sedimentation, surface stability, and accumulation of soil carbonate. Three of the paleosols form prominent (key) beds shown on the map (paleosols 1, 2, and 3). Except for the carbonate-enriched paleosols, the medial facies contains little or no carbonate cement and is poorly exposed. The proximal facies consists chiefly of fine to medium sand, but contains more lenses of coarse sand and granule- to fine-pebble gravel than the medial facies. Fluvial sedimentary structures, such as cross-bedding and channels, are well preserved in the proximal facies adjacent to the Sand Hill fault due in part to calcite precipitated from carbonate-bearing ground water flowing along the Sand Hill fault and in the adjacent hanging-wall fluvial deposits. The spatial distribution and degree of carbonate cementation suggest cross-fault and sub-vertical, fault-parallel flow (Heynekamp and others, 1999). Locally, the Sand Hill fault is well cemented by groundwater carbonate, whereas the proximal facies adjacent to the fault is slightly to moderately cemented by carbonate. The calcite cement in the proximal facies makes it more resistant to erosion than the medial facies, and likely promoted the formation of a series of hills, as much as about 300 m wide, along the east side of the Sand Hill fault. Much of the sand in unit Tsa is weakly consolidated and erodes to form level terrain. Sand grains are mostly subangular to subrounded, and are rich in silica. Sand provenance may include weathered Cretaceous rocks west and northwest of the map area. Bedding is poorly preserved, except in fresh outcrops where it is commonly thin and tabular. Cross-bedding is commonly present in shallow, broad channels. Sediment-transport direction was dominantly toward the south-southwest and south, similar to the trend of the Sand Hill fault. The upper contact of unit Tsa was placed at the base of the lowest clay or silt beds in unit Tsm. The contact between units Tsa and Tsm, at least locally, is an angular unconformity (Heynekamp and others, 1999). Map relationships suggest that unit Tsa grades southward into the lower part of unit Tsm. The lower contact of unit Tsa is not exposed in the map area, because unit Tsa is in fault contact with older units (Tsc and Tss) on the west side of the Sand Hill fault. Exposed

Tan sand and clay unit of the upper Santa Fe Group sediments (upper and middle Miocene)—Mostly tan, fine to medium sand and minor beds of clay and sandstone are well exposed near the northwest corner of the map area, west of the Sand Hill fault. Most of the sand is siliciclastic, subangular to subrounded, and may be derived chiefly from weathered Cretaceous sandstone and deeply weathered Precambrian igneous and metamorphic rocks. The clay is reddish brown and greenish to yellowish brown, well consolidated, and forms three or more tabular beds 1–3 m thick. In surface exposures it is mostly massive where weathered, but is thin- to laminar-bedded where unweathered. The sandstone is composed chiefly of medium to coarse sand weakly cemented by carbonate, and commonly forms beds 1–4 cm thick. These sediments were deposited in subtle upward-fining sequences about 0.5–1 m thick. The sequences consist of a lower part composed of medium to coarse sandstone about 2 cm thick and an upper par composed of fine to medium sand. Clay beds are locally present at the tops of these sequences. Unit Tsc forms gentle slopes that have few outcrops. Near the Sand Hill fault, however, thin beds of coarse sand are well cemented by carbonate and form most of the outcrops of the unit. This localized cementation probably resulted from carbonate-bearing groundwater flowing along and across the Sand Hill fault (Heynekamp and others, 1999). Rare, thin granule lenses are locally present. The lower contact of unit Tsc typically is sharp and is defined by the change from tan sand to pale-reddish-brown silty sand in the underlying unit (Tss). Locally, near the Sand Hill fault, the basal part of unit Tsc may be transitional with the underlying unit (Tss) in areas where the sand is reddish brown over an interval of several meters. Sediment-transport direction was toward the south ( $\pm 20^{\circ}$ ). Unit Tsc was deposited by fluvial processes, probably in a slowly subsiding basin near western margin of the Rio Grande rift. Exposed

thickness is about 60 m

thickness is about 40 m Silty sand unit of the upper Santa Fe Group sediments (upper and middle **Miocene**)—Pale-reddish-brown, mostly silty, fine to medium sand; minor silty and clayey very fine to fine sand; and sparse calcareous medium to coarse sand and clay beds are exposed near the northwest corner of the map area, west of the Sand Hill fault. These sands are non-pebbly. They are well bedded and form tabular beds decimeters to as much as, perhaps, a few meters thick. They are moderately to well cemented by calcite, and are well exposed in steep slopes and stream cuts, especially within 1–2 km of the Sand Hill fault. The pale- to moderate-reddish-brown color of outcrops is enhanced by a coating of reddishbrown wash derived from the erosion of thin, reddish-brown clay beds. Unit Tss

contains many upward-fining, sedimentary sequences about 0.5–2 m thick that

consist of (1) a lower calcareous, medium to coarse sand, centimeter-to-decimeter thick; (2) a middle calcareous, massive, silty, fine to medium sand, about 0.5–1.5 m thick; and (3) an upper non-clayey to clayey fine-sandy sediment, decimeters thick. Near the Sand Hill fault, the lower part of the sequence is well cemented by secondary crystalline calcite that lines local vugs. This secondary calcite probably precipitated from carbonate-bearing groundwater flowing along and across the Sand Hill fault (Heynekamp and others, 1999). Two thick (10 m) sedimentary sequences are well exposed in stream cuts west of the Sand Hill fault. These sequences consist of a lower, cliff-forming part and an upper slope-forming part. Sediment-transport direction was toward the south ( $\pm 20^{\circ}$ ) as indicated by mostly sparse, indistinct channels and by lineations produced by differential ground-water cementation. Much of unit Tss probably consists of fluvial sediments, although some of the sediments may have been deposited in a shallow lake or playa. Exposed thickness at the Sand Hill fault is about 20 m

[Mapped on the east side of the Llano de Albuquerque] **Upper Santa Fe Group sediments, undivided (Pliocene)**—Poorly exposed, slightly cobbly, pebble gravel, pebbly sand, and sand overlain by alluvium and colluvium, undivided (Qac) near the eastern boundary of the map area. Sand is very fine to very coarse. It contains thin (5–50 cm) lenses of pebbly sand and gravel and, locally, thin (5 cm) lenses of silty clay. Clasts are chiefly subangular to rounded sandstone, granite, chert including Pedernal chert of Maldonado and Kelley (2009, and sparse petrified wood and basalt. Unit Ts consists of the gravel unit (Tg), and locally may include the upper part of the pebbly sand unit (Tps) of the Santa Fe Group sediments. Commonly mapped in fractional unit (Qac/Ts), except in one small area near the southeast corner of the map area. Unit Ts is laterally equivalent, at least in part, to the upper sand and gravel member of the Ceja Formation of Connell (2006), Ceja Formation (Williams and Cole, 2007), and the upper sand and gravel unit of the Ceja Formation (Maldonado and others, 2007). Estimated thickness is greater than

#### **EXPLANATION**

----- Contact **Key bed, paleosol 2**—Intermediate paleosol in unit **Tsa** 

— **Key bed, tan sand unit**—Tan sand in unit **Tg**; lower, intermediate, and upper paleosol

# Rim of volcanic crater

## — Flow boundary within lava flow units

#### Mafic dike associated with lava flow unit 7 (Oby<sub>7</sub>) Flow direction of lava

Normal fault—Solid where location is certain; dashed where approximately located; dotted where concealed, bar-and-ball symbol on apparent relative downthrown side. Locations of some concealed faults (dotted) are based chiefly on their geomorphic expression. Locations of other concealed faults (dotted-and-dashed) are based chiefly on interpretation of high-resolution aeromagnetic data (Grauch, 1999; U.S. Geological Survey and SIAL, Ltd., 1997), and are labeled "AM". Dip symbol and number indicate measured dip of fault plane. The names of particular faults on the map correspond with those of Personius and others (1999). Both the Calabacillas and County Dump faults were active during the late Pleistocene. The last displacement on the Calabacillas fault, north of the City of Albuquerque Soil Amendment Facility, was 10 cm about 14,000 years ago; whereas the last

(McCalpin, 2001) ———— Fault—Where located by aeromagnetic survey

Anticline—Solid where location is certain; dashed where approximately located Syncline—Solid where location is certain; dashed where approximately located Monocline, anticlinal bend—Solid where location is certain; dashed where approxi-

displacement on the County Dump fault was 10s of cm about 30,000 years ago

Fluvial transport direction

**Inclined bedding**—Showing strike and dip

Double Eagle 2 O Well drilled for water production and resource evaluation—Showing lease name, hole number, and total depth (TD) in feet

Federal 1  $\diamondsuit$  Dry hole drilled for hydrocarbons—Approximately located. Lease name, hole number, and total depth (TD) in feet.

#### INTRODUCTION

Sediments and lava flows in the map area (map; fig. 1) record alluvial, eolian, colluvial, and volcanic processes during the past 10 or 12 million years in the northern part of the Albuquerque structural basin (Minor and Hudson, 2006). The surficial units on this map are informal allostratigraphic units (discontinuity-bound sequences) of the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 2005), whereas the other map units are

informal lithostratigraphic units. Most of the surficial deposits (post-Santa Fe Group sediments) are poorly exposed. Thin (< 50 cm), discontinuous deposits of active eolian sand (Qea) and sheetwash (Qsw) and small deposits of artificial fill (af) less than about 25 m wide were not mapped. Locally, along the Calabacillas and County Dump normal faults, there are thick (perhaps as much as 50 m) deposits that accumulated on the east (downthrown) sides of these faults in areas mapped as Qes, Qac/Tg, and Qsw/Qao. These fault-related deposits were not mapped, because they are mantled by younger deposits. These fault-related deposits are similar to those of unit QTs, near the northwest corner of the map area and to those along and near the County Dump fault south of the map area (Machette, 1978a; Machette and others, 1997; McCalpin, 1997; Shroba and others, 2003). Contacts between map units were determined photogrammetrically using a Kern PG-2 Stereoplotter and 1:36,000-scale color aerial photographs taken in 1994. Fractional map symbols (for example, Qac/Tq and Qsw/Qbv<sub>1</sub>) are used where undivided alluvium and colluvium or sheetwash deposits mantle older sediments or lava flows and have red stipple. For descriptions of fractional units refer to the descriptions of the individual units. Age assignments for surficial deposits are based chiefly on the relative degree of modification of original surface morphology, relative heights above channels of modern intermittent streams, and degree of soil development. The terms "soil" and "soils" refer to pedogenic soils formed in surficial deposits. Soil-horizon designations are those of the Soil Survey Staff (1975) and Birkeland (1999). Most of the surficial deposits are calcareous, and contain both primary and secondary calcium carbonate. Stages of secondary calcium carbonate morphology (referred to as stages I through IV in this report) are those of Gile and others (1966) and Machette (1985). Grain or particle sizes of surficial deposits in map-unit descriptions are field estimates. Size

limits for sand (2-0.05 mm), silt (0.05-0.002 mm), and clay (< 0.002 mm) are those of the Soil

Survey Staff (1951). In descriptions of surficial map units, the term "clasts" refers to granules and larger particles (> 2 mm in diameter), whereas the term "matrix" refers to sand and finer particles (≤ 2 mm in diameter). In this report, the terms "alluvium" and "alluvial" refer to material transported by running water confined to channels (stream alluvium) as well as by running water not confined to channels (sheetwash). The term "colluvium" refers to all rock and sediment transported downslope chiefly by gravity (Hilgard, 1892; Merrill, 1897). Material on slopes is transported chiefly by mass-movement (gravity-driven) processes, such as creep and debris flow, locally aided by running water not confined to channels (sheetwash). The term "fan deposits" refers to material transported by intermittent streams and debris flows and deposited in fan-shaped accumulations near the base of moderate to steep slopes. Surficial map units that include debrisflow deposits probably also include hyperconcentrated-flow deposits. These latter deposits have bedding and sorting characteristics intermediate between those of stream-flow and debris-flow deposits (Pierson and Costa, 1987; Meyer and Wells, 1997). The clasts in many of the surficial deposits in the map area were derived chiefly from the gravel unit of the upper Santa Fe Group sediments (Tg). Commonly they are subangular to rounded sandstone, porphyritic volcanic rock, red granite, gneiss, chert, sparse quartzite, petrified wood, and basalt. Clasts in unit Tg were derived primarily from sources west and northwest of the map area. Those in surficial deposits that overlie lava flows near the southeast corner of the map area commonly are angular and subangular basalt fragments. Clasts referred to above (as "basalt" as well as in descriptions of the gravel unit of the upper Santa Fe Group sediments (Tg) and upper Santa Fe Group sediments, undivided (Ts)) probably also include basaltic andesite and possibly other volcanic rocks of basaltic composition.

Dry matrix colors of the surficial deposits were determined by comparison with Munsell Soil Color Charts (Munsell Color, 1973). Colors of the surficial deposits generally are similar to those of the sediments and (or) bedrock from which they were derived. The colors of the surficial deposits commonly range from white (2.5Y 8/1) to light reddish brown (7.5YR 6/4). Colors of the lava flows and cinder deposits were determined by comparison with a Geological Society of America Rock-Color Chart (Rock-Color Chart Committee, 1995). Colors of the upper Santa Fe Group sediments are field terms and were not determined with color charts. The gently rolling upland that covers much of the map area in this report is referred to as the Llano de Albuquerque (Bryan and McCann, 1938; fig. 1) or popularly referred to as the West Mesa (equivalent to the Ceja Mesa of Kelley, 1977). This version of The Volcanoes geologic map in this release depicts landforms with shaded relief generated from the National Elevation Dataset (http://ned.usgs.gov) tepresenting altitudes interpolated to 10-m grid spacing. Shading illumination is from the northwest at 45° above the horizon and serves to highlight fault scarps and other linear topographic features. Shaded relief was first used on geologic maps printed in the United States of America more than 145 years ago. The two geologic maps prepared by John S. Newberry that accompanied a report by Joseph C. Ives on the 1857–1858 exploration of the lower Colorado River had shaded relief topography that was produced by ruled tints. This method of showing shaded relief was developed by the topographer

and artist Baron F.W. von Egloffstein (McKinney, 2002). The original name for this quadrangle was Volcano Ranch, but the quadrangle was renamed The es when it was revised in 1990. We used the name The Volcanoes quadrangle for this may but used the former Volcano Ranch 7.5 minute series quadrangle for our topographic base. The former topographic base was prepared in 1954 and later revised based on aerial photography taken in 1967 and 1972. We used this 1954 base map for its clarity of geologic relations relative to topography, at the expense of showing more recently added cultural elements to the topographic base. The 1990 The Volcanoes 7.5 minute map shows features not shown on the Volcano Ranch map, such as the Double Eagle II Airport and the City of Albuquerque Soil Amendment Facility. We have added the boundaries of Petroglyph National Monument to the 1954 topographic base. The authors mapped the geology in 1996–1999. The primary mapping responsibilities were as follows. Thompson mapped the volcanic rocks and related deposits in the southeastern part of the map area. Shroba described and estimated the ages of the surficial deposits in the map area and mapped some of the surficial deposits on and east of the Llano de Albuquerque. Menges mapped most of the surficial deposits on and east of Llano de Albuquerque. Schmidt mapped the surficial deposits, upper Santa Fe Group sediments, and faults west of the Llano de Albuquerque, Personius mapped the faults on and east of Llano de Albuquerque. Brandt prepared the digital database for the geologic map and the shaded relief base materials. Metric units are used in this report, except for measurements in drill holes, which were recorded

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STRATIGRAPHY OF DEEP DRILL HOLES IN AND NEAR THE MAP AREA Six deep drill holes in and near the map area provide significant information concerning subsurface Santa Fe Group sediments (table 1). The deepest hole was drilled for hydrocarbon exploration in Cretaceous units beneath Santa Fe Group sediments. The other five drill holes are

water wells.

Lithologic descriptions and a generalized cross section indicate that the drill hole penetrated at least 16,830 ft (5,133 m) of Tertiary sediments and bottomed in Mesozoic rocks (table 1). The Tertiary sediments consist of about 8,550 ft (2,608 m) of Santa Fe Group sediments, 7,170 ft (2,187 m) of unit of Isleta no. 2 of Lozinsky (1988, 1994), and 1,110 ft (338 m) of Galisteo Formation (Lozinsky, 1994). In the Albuquerque basin, Lozinsky's unit of Isleta no. 2 commonly consists of purplish-red to gray, well indurated, poorly to moderately sorted, fine- to coarse-grained, volcaniclastic sandstone that contains interbeds of claystone and silicic- to intermediate-volcanic flows and tuffs (Lozinsky, 1994). The drill hole also penetrated about 1.655 ft (504 m) of Cretaceous rocks and about 900 ft (274 m) of Jurassic rocks. Inferred thicknesses of lithologic units in the Santa Fe Group are based on interpretation of cuttings from a nearby water well (B.D. Stone and D.A. Sawyer, U.S. Geological Survey written commun., 1999). The U.S. Geological Survey drilled well 2 in 1981 to a total depth of 1,828 ft (557 m). Lithologic logs and grain-size analyses of the cuttings suggest that the drill hole penetrated (from top to bottom) 8 ft (2 m) of surficial deposits, 34 ft (10 m) of basalt, and 1,786 ft (544 m) of Santa Fe Group sediments. The upper 746 ft (228 m) of the Santa Fe Group sediments commonly

Shell Oil Company drilled West Mesa Federal 1 in 1983 to a total depth of 19,375 ft (5,905 m).

contains 10-30 percent granules plus gravel (> 2 mm), whereas the lower 1,040 ft (317 m) consists of sand and finer material. The greatest amount of sand and coarser material (about 90 percent > 0.062 mm) is in the upper 291 ft (89 m) of the Santa Fe Group sediments. These coarse-grained sediments may be equivalent to gravel unit (Tg) and the pebbly sand unit (Tps) of the Santa Fe Group sediments mapped near the western boundary of the map area. The content of silt plus clay (< 0.062 mm) varies with depth, and is about 10 percent at 42–333 ft (13–101 m), 20–30 percent at 333–788 ft (101–240 m), 40–60 percent at 788–1,289 ft (240–393 m), and about 35 percent at

1,289–1,828 ft (393–557 m) (Wilkins, 1987). Facility 1, and Double Eagle 2) penetrated Santa Fe Group sediments to total depths of 1,708-3,030 ft (521-924 m). See table 1 for additional information concerning Santa Fe Group lithologic units

.5-minute quadrangle. It is about 190 m east and about 3,660 m south of the southeast corner of the The Volcanoes quadrangle. The core hole was drilled by the U.S. Geological Survey in 1996 to a total depth of 1,560 ft (476 m) to determine the lithostratigraphy and hydrogeologic characteristics of the aquifer system. Sampling recovered 760.6 ft (231.8 m) of core. The core hole penetrated about 19 ft (6 m) of Ouaternary eolian sand and alluvium; 78 ft (24 m) of the upper gravelly unit of the Santa Fe Group; and at least 1,463 ft (446 m) of the middle unit of the Santa Fe Group (Stone and others, 1998). The upper gravelly unit of the Santa Fe Group consists chiefly sand, gravel, and lenses of pebbly sand, silt, and clay. The middle unit of the Santa Fe Group is mostly interbedded sand, silty sand, silty clay, and clay (Stone and others, 1998). The upper gravelly unit of the Santa Fe Group probably is laterally equivalent to the gravel unit of the upper Santa Fe Group sediments (Tg) and the pebbly sand unit of the upper Santa Fe Group sediments (Tps) in The Volcanoes quadrangle, the Ceja Member of the Santa Fe Formation of Kelley (1977), and the Sierra Ladrones formation (Machette, 1978b; Stone and others, 1998).

The other three water wells (Black Ranch Test Well, City of Albuquerque Soil Amendment

The 98th Street core hole is located just north of Interstate 40 in the adjacent Albuquerque Wes

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